Part I: Newton’s Laws
Chapter 4: Kinematics in Two Dimensions

4.1 Motion in Two Dimensions
Vector it up!

\[ \vec{v} = \frac{d\vec{r}}{dt} \]

\[ d\vec{r} = \vec{v} \, dt \]

\[ \Delta \vec{r} = \int_{t_i}^{t_f} \vec{v} \, dt \]

Component equations:

\[ \Delta x = \int_{t_i}^{t_f} v_x \, dt \]

\[ \Delta y = \int_{t_i}^{t_f} v_y \, dt \]

The displacement is \( \Delta \vec{r} = \Delta x \hat{i} + \Delta y \hat{j} \)

The average velocity points in the direction of \( \Delta \vec{r} \):
Delta $v$'s: (1) speeding up, (2) slowing down, (3) changing direction

- $\vec{a}$ is parallel to $\vec{v}$. Only speed is changing.
- Both speed and direction are changing. $\vec{a}$ has components parallel and perpendicular to $\vec{v}$.
- $\vec{a}$ is perpendicular to $\vec{v}$. Only direction is changing.

- (1) and (2) can be grouped together as changing magnitude.
- How do the $\Delta \vec{v}$'s look compared to the trajectory's arc?
- How do we “see” changing “magnitude and direction” modes?
(a) Building Intuition, (b) Practical.

The parallel component is associated with a change of speed.

Instantaneous velocity

The perpendicular component is associated with a change of direction.

Instantaneous acceleration

The $x$- and $y$-components are mathematically more convenient.
A problem for you to do: You are navigating a large-radius turn in your high-performance sports car\(^1\) at high speed, trying to set a personal best on a closed course. Create a very rich diagram that encapsulates these features:

- Shortly before the turn we start to slow down.
- We continue to slow down in the early part of the turn.
- Through the central region of the turn you are only changing direction.
- Heading out of the turn we are speeding up.
- After the turn we continue to speed up.

Your diagram should show the trajectory and representative points with velocity and acceleration vectors drawn and labeled. Markup your diagram with short comments to make it a self-contained portrait.

\(^1\)Do you have a favorite? Let your instructor know!